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A simplified problem in which the element of chance is retained may be constructed by supposing the particles of glass replaced by thin parallel discs which are distributed entirely at random over a certain stratum. We may go further and imagine the discs limited to a particular plane. Each disc is supposed to exercise a minute retarding influence on the light which traverses it, and they are supposed to be so numerous that it is improbable that a ray can pass the plane without encountering a large number. A certain number (m) of encounters is more probable than any other, but if every ray encountered the same number of discs the retardation would be uniform and lead to no disturbance.

It is a question of probabilities to determine the chance of a prescribed number of encounters, or of a prescribed deviation from the mean. In the notation of the integral calculus the chance of the deviation from m lying between $\pm r$ is *

$$\frac{2}{\sqrt{\pi}} \int_0^{\tau} e^{-\tau^2} d\tau,$$

where $\tau = r / \sqrt{(2m)}$. This is equal to .84 when $\tau = 1.0$, or $r = \sqrt{(2m)}$; so that the chance is comparatively small of a deviation from m exceeding $\pm \sqrt{(2m)}$.

To represent the glass powder occupying a stratum of 2 cm. thick we may perhaps suppose that $m = 72$. There would thus be a moderate chance of a difference of retardations equal to, say, one-fifth of the extreme difference corresponding to a substitution of glass for liquid throughout the whole thickness. The range of wave-lengths in the light regularly transmitted by the powder would thus be about five times the range of wave-lengths still unseparated in a spectroscope of equal (2 cm.) thickness. Of course, no calculation of this kind can give more than a rough idea of the action of the powder, whose disposition, though partly a

matter of chance, is also influenced by mechanical considerations; but it appears, at any rate, that the character of the light regularly transmitted by the powder is such as may reasonably be explained.

As regards the size of the grains of glass it will be seen that as great or a greater degree of purity may be obtained in a given thickness from coarse grains as from fine ones, but the light not regularly transmitted is dispersed through smaller angles. Here, again, the comparison with the regularly disposed prisms of an actual spectroscope is useful.

At the close of the lecture the failure of transparency, which arises from the presence of particles, small compared to the wave-length of light was discussed. The tints of the setting sun were illustrated by passing the light from the electric lamp through a liquid in which a precipitate of sulphur was slowly forming.* The lecturer gave reasons for his opinion that the blue of the sky is not wholly, or even principally, due to particles of foreign matter. The molecules of air themselves are competent to disperse a light not greatly inferior in brightness to that which we receive from the sky.

R.

DISTRIBUTION OF THE KEEWATIN IN MINNESOTA.

IN Minnesota the lithological characters of that part of the Algonkian known as Lower Huronian or Keewatin are necessary in the recognition of the stratigraphic subdivisions of geographically separated localities. The Keewatin carries the first clearly defined sediments of this portion of the globe. Often the clastic origin of the rocks has been so completely obliterated by alteration due largely to dynamic metamorphism that it is difficult to distinguish them from their associates. At the bottom of the series is usually a quartzite which is locally con-

* See *Phil. Mag.* 1899, Vol. XLVII., p. 251.

* Op. cit., 1881, Vol. XII., 96.

glomeratic and not infrequently a quartz—to mica-schist in petrographic habit.

The following are the localities of accepted Keewatin: 1. Lake of the Woods district. Four ridges corresponding to as many upward folds of the Archean contain in the troughs between them the softer mica-schists, chlorite-schists, agglomerates, etc., of the Keewatin. [Compare Lawson, Geol. and Nat. Hist. Sur. Can. 1885, cc., pp. 10-22.] On the Minnesota side of the lake there is less opportunity for study; it is probable that not all three intervening depressions will be found south of the international boundary. 2. Along Rainy River and in the Rainy Lake region a double trough formed by the earlier rocks contains the Lower Huronian series. While the rocks consist largely of volcanics now altered to hornblende—and hornblendic schists, there are also fissile glossy schists, carrying water-worn pebbles, breccias, graywackes, etc. The Lower Huronian rock exposures of the northern Rainy Lake basin can be traced in direct continuity into the rocks in the Lake of the Woods district already noted. [Lawson, Amer. Jour. Sci. 1887, vol. 133, pp. 477, 478.] In 1894 H. V. Winchell and U. S. Grant carefully mapped this region and described a belt of Keewatin "conglomerates, slates, sericitic, chloritic and hornblendic schists, agglomerates, graywackes and more or less altered igneous rocks, both acid and basic." The most important belt enters Minnesota between Rainy Lake City and the north shore of Jackfish Bay. The general direction of this belt is W. 15° - 20° S., according to the map referred to, the greater part of the area in view lying within Ontario. Many of the gold locations around Rainy Lake lie in the Keewatin rock areas. [Prelim. Rep. on Rainy L. gold region 23d Ann. Rep. Geol. and Nat. Hist. Sur. Minn., 1895, pp. 36-104.] 3. The most eastern of the successive belts of Keewatin rocks extending

from Ontario into Minnesota is that in exposure along the boundary between the head of Basswood Lake and Lake Saganaga, with Knife Lake as a sort of axis. This belt, followed in a W., S. W. direction, becomes effectually covered by glacial drift a short distance beyond Vermilion Lake. Two or three exposures are reported from near the Mississippi River. The rocks are conglomerates, sericitic schists, more or less altered eruptives and the remarkable segregations of hematite mined between Tower and Ely and occurring in what have thus far proved leaner deposits eastward, possibly into the Kaministiquia district of Ontario. Economically this is the most important Keewatin area in Minnesota thus far explored.

In the eastern and central portions of the State are rocks hitherto not generally regarded as Keewatin: 4. Several areas may be grouped: (a) At Thomson, Carlton and southwestward lies an extensive mass of quartzose clastics in which occur lenses or beds of slate regarded by Irving and N. H. Winchell as Animiké; locally they are conglomeratic. (b) Around Barnum and Moose Lake lies a series of hornblende-biotite schists dipping at a low angle southward; the texture is rather fine and the general aspect of the rocks fresh and sharply crystalline. (c) West of Sturgeon Lake lies a belt of hornblende schists dipping at a high angle or standing vertical with interleaved granitic, gneissic and quartzose masses. These schists are, in places, garnetiferous and frequently abound in lenses and stringers of quartz. (d) Still farther southwestward, on the Kettle River, are exposures of mica schists with veins and dikes of granite within the schists, while (e) at Ann River and westward through Mille Lacs, Benton, Sherburne and Stearns counties are enormous masses of hornblende-biotite granite. These granites in their freshest condition carry augite cores within

the hornblende-biotite areas and in several localities are in apparent proximity to gabbro. (f) Farther north, on the Mississippi River, from Two Rivers past Little Falls to the valley of the Elk River, are extensive exposures of a fine-grained hornblende-biotite schist carrying bosses of gabbro and lenses of quartz-diorite [J. H. Kloos, *Neu. Jahrb. für. Min.*, 1877, S. 225] and, also locally, thickly studded with staurolite crystals and garnets. (g) Finally the interesting masses of epidote granite and associated basic eruptives of Western Stearns, Todd and Cass counties.

I have reached the conclusion that all the areas enumerated under (a) to (g) above belong to the same geologic time division, viz., the Keewatin. The clastics, partially altered clastics and thoroughly crystalline schists in the areas (a), (b), (c), (d) and (f) belong to a single rock series and the granites and gabbros of areas (d), (e), (f) and (g) are eruptive through them. The staurolite, garnet, quartz-lenses, etc., essentially contact minerals, bear circumstantial evidence of the proximity of eruptive masses of granite or gabbro even where such masses are not now seen owing to enormous subsequent erosion or the covering of glacial drift.

Among the considerations upon which the foregoing conclusion was reached are the following: 1. The quartzose clastics and hornblende-biotite schists, which are admittedly one and the same rock series [Irving, R. D., *Fifth An. Rep. Director U. S. Geol. Surv.*, p. 196], can be traced by petrographic and structural characters through Mahtowa, Barnum and Moose Lake in an almost continuous succession of exposures from the Thomson conglomerate to the coarser garnetiferous schists, carrying quartz stringers and lenses in considerable profusion west of Sturgeon Lake; and these in turn through reported exposures [Hopewell Clarke, *Land Commis-*

sioner, St. Paul and Duluth R. R.] to the Snake River valley schists filled with dikes of granite. 2. The relation of the Snake River granite dikes in T. 42, R. 23 W., and the granites of Kanabec, Mille Lacs, Benton, Sherburne and Stearns counties cannot be traced in the field, yet their petrographic characters are essentially alike, and they have always been assumed to be the same. 3. The staurolite-bearing southern border of the Mississippi Valley schists disappears beneath the glacial drift in striking nearness to the granites of Stearns and Morrison counties. 4. Nowhere in Minnesota has this type of granite been found intrusive into or through the Animiké [for illustration compare Irving, R. D., *Seventh An. Rep. Director U. S. Geol. Surv.*, pp. 421, 422]; in several places in central North America it is reported as penetrating and lying upon the Keewatin [e. g., Lawson, A. C., *Geol. and Nat. Hist. Surv. Can.*, 1885, cc., p. 14].

Summarizing: The Keewatin of Minnesota, therefore, occupies a much greater area than has hitherto been assigned to it, since it underlies the large central region of the State. It here consists of two distinct rock groups, one a clastic-crystalline and the other an eruptive, partly acid and partly basic, breaking into and through the former. The two exhibit in places a typical eruptive unconformity, yet volcanic activity apparently ceased before overlying rocks were laid down upon the intermingled eruptive and clastic material.

The hornblende-biotite granites of central Minnesota constitute enormous erupted masses, probably laccolitic in structure, which towards the northeast give place to a system of dikes which break through the schists and cause the greatest stratigraphic confusion. It is in this region that the schists become thickly studded with contact minerals.

The succession of characters representing

the transition of a elastic rock into a schist, and the loading of the schist with accessory minerals in the vicinity of the intruding eruptives, is identical with what can be seen in the Black Hills, and described for the same region by Van Hise [Bull. Geol. Soc. Am., Vol. I., pp. 209-211]. The metasomatic changes of the quartz clastics to crystalline schists in Minnesota is a process identical with what has been so fully discussed for the Penokee Range of Wisconsin [Van Hise, Amer. Jour. Sci., Vol. 131, pp. 453-459] and recognized in other localities too numerous to cite.

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THE ASSOCIATION OF AMERICAN AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS.

THE thirteenth annual convention of the Association of American Agricultural Colleges and Experiment Stations was held at San Francisco, July 5th-7th, in conjunction with the Association of Official Agricultural Chemists. Delegates from 34 States and Territories were in attendance. The welcome of the city was voiced by Mayor Phelan, and many courtesies were extended the visitors by individuals and associations representing the State of California. Especial mention should be made of the untiring efforts of Professor M. E. Jaffa, of the University of California, to facilitate the business of the convention and secure the personal comfort of the delegates.

Dr. H. P. Armsby, director of the experiment station connected with the Pennsylvania State College, presided at the general sessions and delivered the President's annual address. This was a clear and forcible presentation of the central purpose of the experiment stations as institutions of higher education. By original research they are to increase our knowledge of the principles underlying the art of

agriculture and show the farmer how these may be applied to the advantage of his practice. The station should be the source of knowledge and inspiration for the agricultural college—the cap-stone of agricultural education. As such it should be divorced as far as possible from the routine elementary instruction of the college. At its head should be a director who inspires rather than directs.

By appointment President M. H. Buckingham, of the University of Vermont, pronounced a graceful and discriminating eulogy on Senator Justin S. Morrill and introduced memorial resolutions which were unanimously adopted. In discussing Senator Morrill's relation to the great educational measures with which his name will always be connected, President Buckingham said that the central idea which the great statesman intended to embody in this legislation was that it was possible by a suitable form of higher education to lift the arts and industries to the plane hitherto occupied alone by the professions. This the speaker claimed was a unique American idea, and its practical crystallization in the Morrill Acts of 1862 and 1890 placed them among the epoch-making acts of the American Congress.

The fourth report of progress of the Committee on Methods of Teaching Agriculture was read by Director A. C. True, secretary of the committee. This report presented a syllabus of a course in zootechny which was limited to the theory and practice of the production of the normal useful animal. Zootechny was divided by the committee into three main branches: (1) types and breeds of useful animals; (2) feeding, and (3) hygiene and management. It was deemed most feasible that the teaching of the general principles under each one of these heads should be immediately followed by the application of the principles to practice as regards different kinds of ani-